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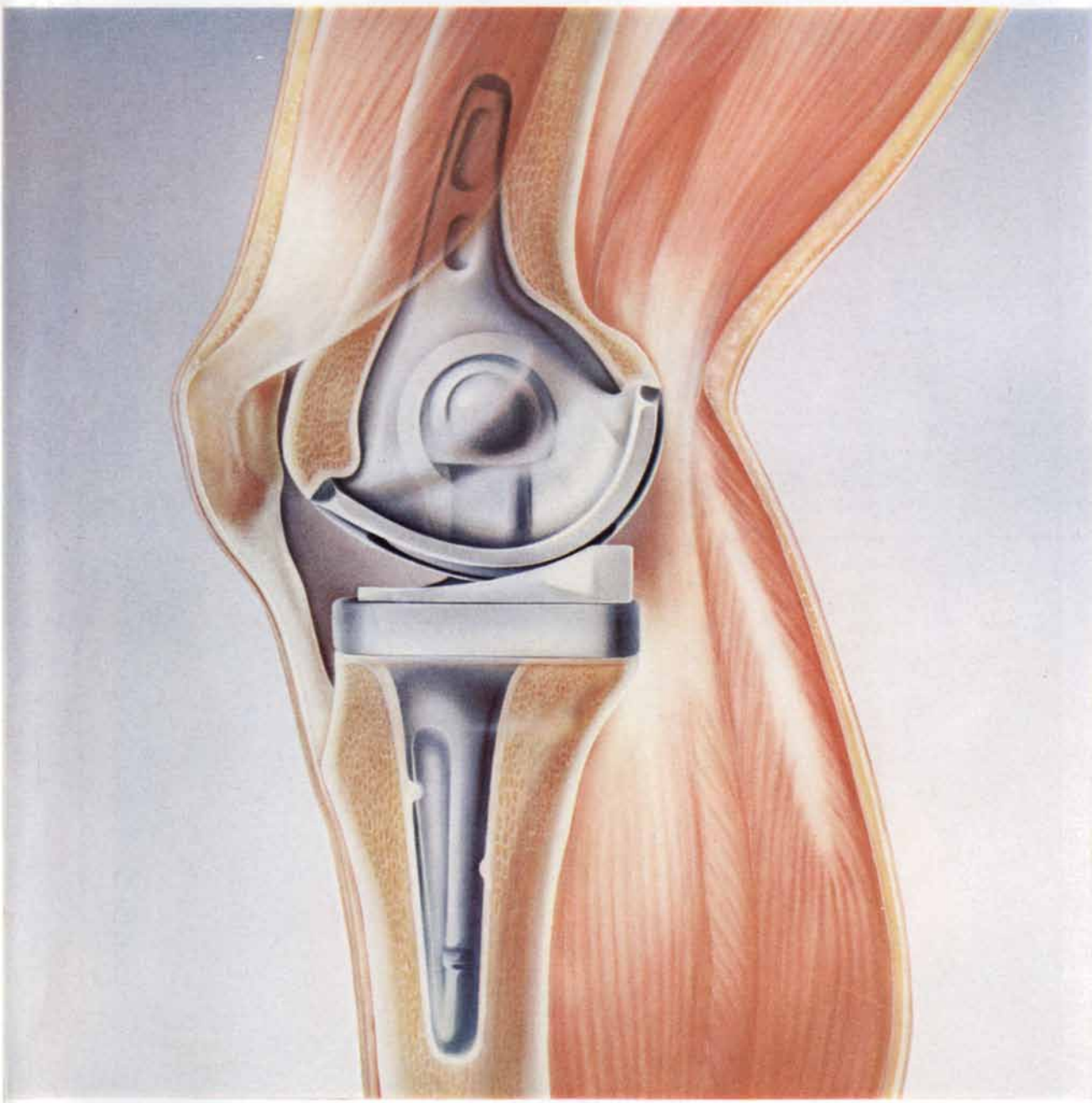

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MATHEMATICAL GAMES

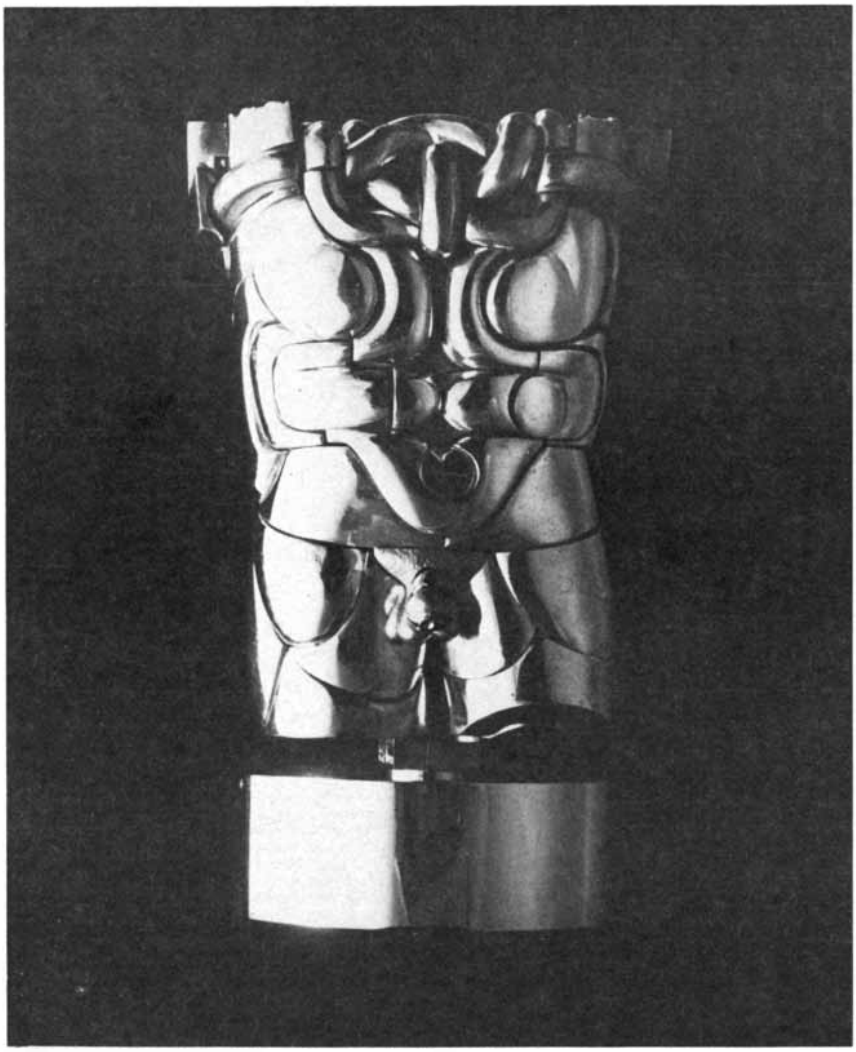
The sculpture of Miguel Berrocal can be taken apart like an interlocking mechanical puzzle

by Martin Gardner

"We then fell into a disquisition whether there is any beauty independent of utility. The General maintained there was not. Dr. Johnson maintained that there was; and he instanced a coffee-cup which he held in his hand, the painting of which was of no real use, as the cup would hold the coffee equally well if plain; yet the painting was beautiful."

—JAMES BOSWELL,
Life of Samuel Johnson

The purpose of this month's column is to introduce readers to Miguel Berrocal, the foremost living Spanish sculptor. Berrocal is already a cult figure in Europe with a steadily growing following, but he is surprisingly little known in the U.S. Before detailing Berrocal's remarkable achievement, however, and explaining why his sculpture should be discussed in a column on recreational mathematics, we must consider one of the oldest categories of mechanical puzzles.



***Miguel Berrocal's* Goliath**

Is there any reader who has not at some time held one of those puzzles made of wood pieces so cleverly interlocked that they are quite difficult to separate? These objects are usually called Chinese puzzles, and once they have been taken apart putting them back together again can be even more challenging. There is usually a single piece, called the key, that must be removed first in order to disassemble the puzzle. In many such puzzles the pieces must be replaced in a certain sequence in which the key is always inserted last to lock the other pieces firmly in place. Hundreds of differently structured puzzles of this type have been sold around the world for centuries, most of them invented anonymously (even though hundreds of patents for unmarketed variations on the puzzles have been issued).

Almost nothing is known of the early history of these puzzles, but "Chinese puzzles" is probably a misnomer. East Asian countries were certainly producing puzzles of this kind as early as the 18th century, but so were European countries. Moreover, other kinds of mechanical puzzles of unquestionably Western origin were also called Chinese puzzles. As Joseph Needham writes in Volume III of *Science and Civilization in China:* "Perhaps Europeans were inclined to ascribe to puzzles the name of what was, to them, a puzzling civilization."

Chinese puzzles can have as few as three pieces, but the simplest nontrivial model is the popular six-piece puzzle shown in the top illustration on page 16. The six pieces are shown below the assembled puzzle as they were depicted by "Professor Hoffmann" (the pseudonym of Angelo Lewis) in his 1893 book on mechanical puzzles, *Puzzles Old and New*. The unnotched bar at the far left is the key. A different set of six pieces appeared earlier in *The Magician's Own Book,* an anonymous work first published in the U.S. in 1857. Anthony S. Filipiak, in *100 Puzzles: How to Make and Solve Them* (A. S. Barnes and Co., 1942), calls such an assembly a "six-piece burr puzzle," presumably because it looks like a seed burr. The name "burr" is now commonly applied to all puzzles of this kind.

Manufactured versions of the six-piece burr are seldom alike. This fact suggested to Filipiak a surprisingly difficult problem in geometric combinatorics. Imagine that the middle part of the puzzle's unnotched key piece is divided

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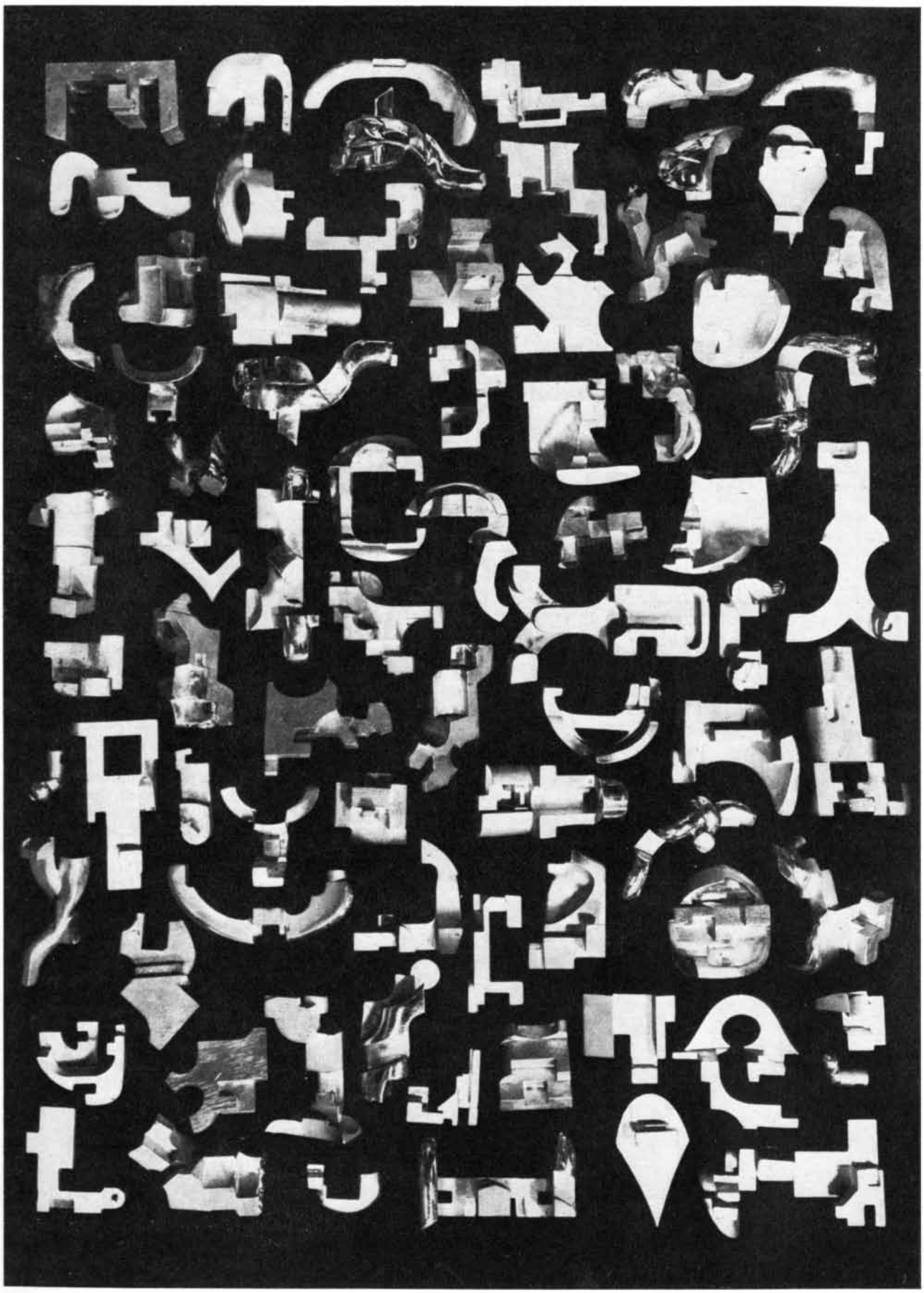

The 80 pieces of **Goliath**

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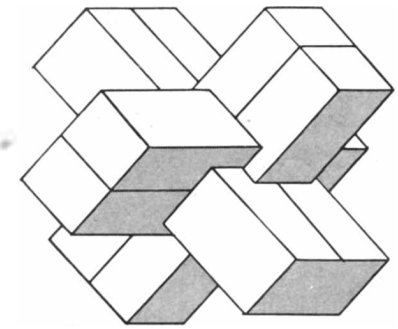
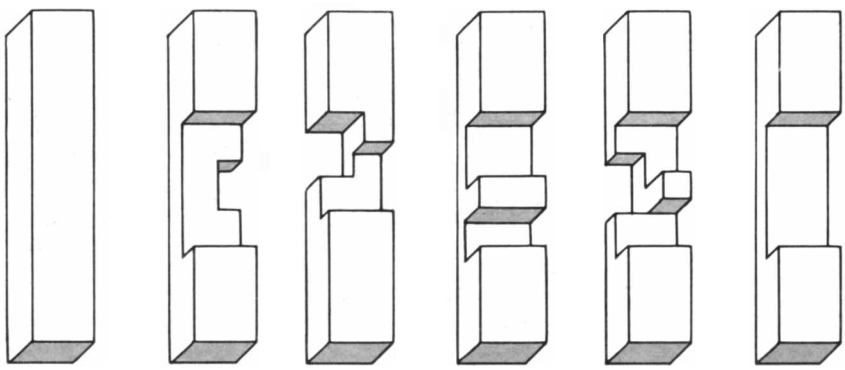
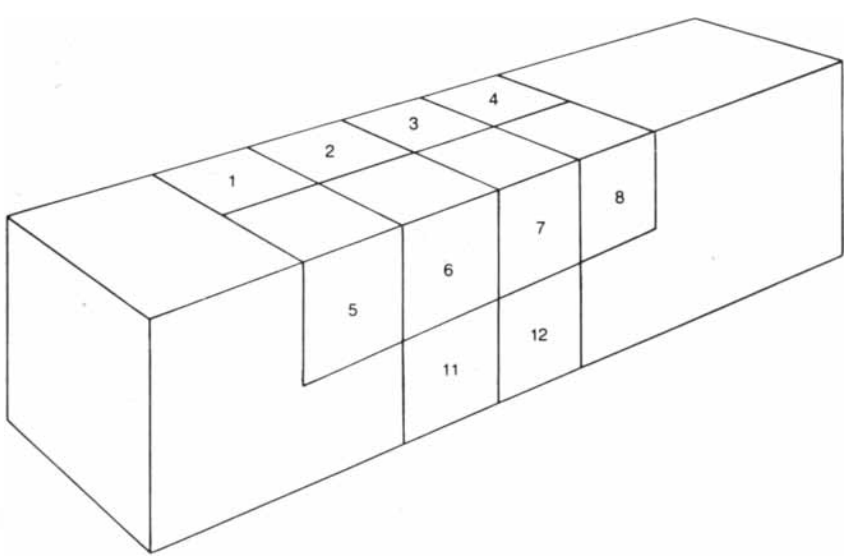




A six-piece "burr" puzzle

into 12 unit cubes as is shown in the illustration below. The sides of each cube are equal to half the depth of the key. There are four more cubes under the cubes numbered 2, 3, 6 and 7, but only two of them, 11 and 12, can be seen in the illustration. Each piece of any six-piece burr can now be described by stating which of the 12 unit cubes have been removed.

Since each unit cube is either present or absent in a piece of the puzzle, there are 2^{12}, or 4,096, possible patterns in all. Those that divide the bar into separate pieces must of course be eliminated. Among the remaining pieces simple rotations and end-for-end turns account for eight repetitions of any single pattern. Therefore for each pattern seven duplicates can be eliminated. (Mirror reflections of asymmetric configurations are not excluded.) Finally, there are some patterns that for mechanical reasons will not combine with any other pattern to form an interlocking structure. These patterns can also be eliminated. After the above exclusions have been made, how many configurations remain? In other words, how many of the 4,096 patterns can be utilized in a six-piece burr puzzle? Filipiak believed there were 432.



Pattern for the pieces of a burr puzzle

In recent years three mathematicians have employed computer programs to attack the problem. They are William H. Cutler of Wartburg College in Waverly, Iowa, Robert H. Mackay of London and C. Arthur Cross of Cheshire in England. Cutler and Cross now agree that the number of usable pieces is 369. Sixty-seven of those pieces, however, can be utilized only with duplicates and two can be utilized only with triplicates, making a set of 440 pieces in all. A second question, still unsolved, now arises: How many different six-piece burr puzzles can be made from this set? Interlockings that are impossible to put together or take apart must be excluded. It is also advisable to omit constructions with internal holes, because they usually do not hold together well. Given these constraints, Cutler's computer program found the number of distinct six-piece burrs to be 119,963, but Cutler is not satisfied that the program is free from errors. Interested readers can write to him for details.

I know of only two places where more elaborate kinds of burr puzzles can be obtained. In England, Pentangle (Over Wallop, Hants, England S020 8JA) will send a catalogue of their mechanical-puzzle line, which includes several handsome wood puzzles of the burr type. The one called "Grandpa Chuck" has 96 pieces. In the U.S. if readers send a stamped and self-addressed business envelope to Stewart T. Coffin (Old Sudbury Road, R.F.D. 1, Lincoln, Mass. 01773), he will send back a brochure for his unusual line of original burr puzzles. His prices are high because all the puzzles are handcrafted from hardwoods. For several years Coffin issued an occasional newsletter, *Puzzle Craft,* that dealt with the history and construction of mechanical puzzles. He tells me he will send a 24-page reprint of the six issues that have appeared, along with the brochure, for $2 postpaid.

From time to time Chinese puzzles have been manufactured to resemble familiar objects: a car, a pistol, a battleship, an airplane, a pagoda, a barrel, an egg and various animals. Most interlocking wood puzzles are not designed to represent anything, and yet because of their symmetries they are always pleasing to look at. It is the representational models that are usually low in aesthetic appeal. This brings me to Berrocal. As far as I know he is the first

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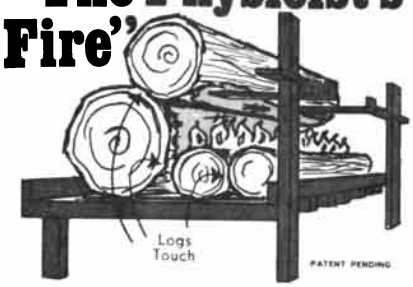
"The Physicist's Fire"



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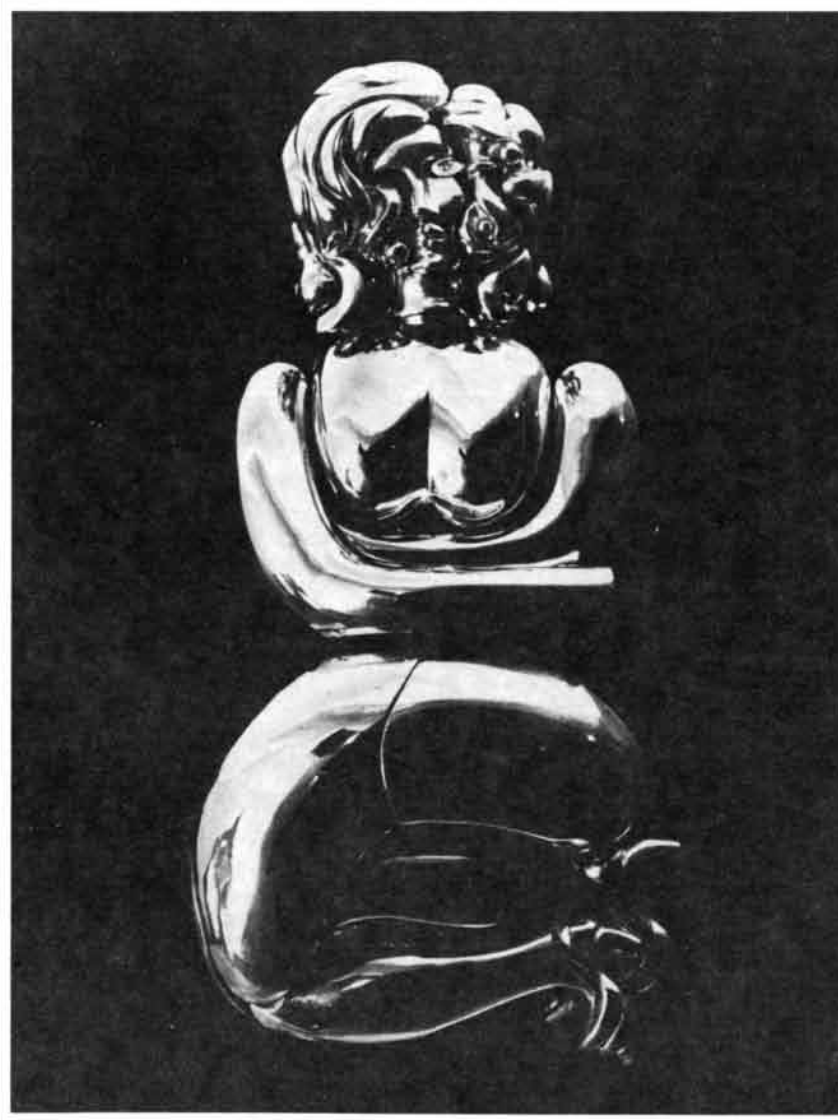
person to combine the interlocking Chinese puzzle with high art.

Berrocal was born in 1933 into a middle-class Spanish family in Málaga. He studied mathematics and architecture at the University of Madrid, then art in Paris and Rome before settling in Negrar, a suburb of Verona. He lives there today in a palatial villa with his second wife, Princess Cristina. (She is the granddaughter of the last king of Portugal.) Berrocal presides over a 200-employee foundry in Negrar that casts not only his own work but also much work of other European sculptors. "I am the boss of the sculptors' Mafia," he once said. Like Pablo Picasso and Salvador Dali, the most notable Spanish painters of the 20th century, Berrocal is a virtuoso who combines a prodigious output with skillful public relations and a dazzling, immodest personality.

It is impossible to appreciate the unique combination of values in Berrocal's work—visual beauty, tactile pleasure, humor and the intellectual stimulation of a three-dimensional combinatorial puzzle—until one has taken a Berrocal apart and put it back together several times. For example, consider the two Berrocals shown stacked together in the illustration below. The head, called *Portrait de Michèle,* consists of 17 separate, curiously shaped elements, each one designed to be an individual piece of abstract sculpture and also pleasing to the fingers. The body, called *La Totoche* (The Plump Lady), is one of several bodies onto which the head can be fitted. It can be broken down into 12 pieces.

Berrocal introduced the term "multiples" for the mass-produced copies that he casts of each of his works. His edition of *Portrait de Michèle* is typical: six multiples in solid gold, 500 in sterling silver and 9,500 in nickel-plated bronze. Each copy is numbered and signed and flawlessly crafted with engineering precision. In every Berrocal the pieces must



Portrait de Michèle (head) ***attached to*** **La Totoche (body)**

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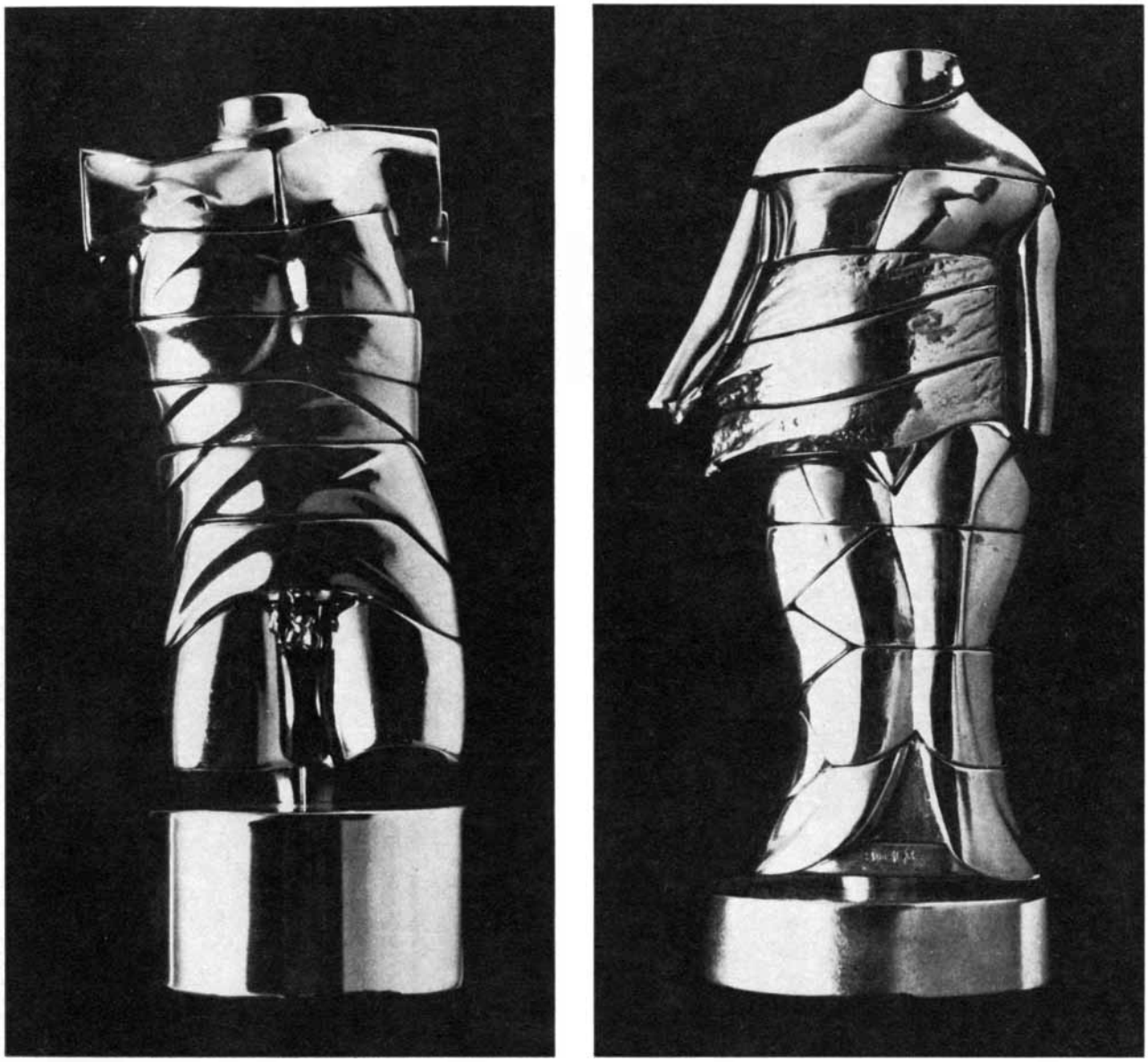
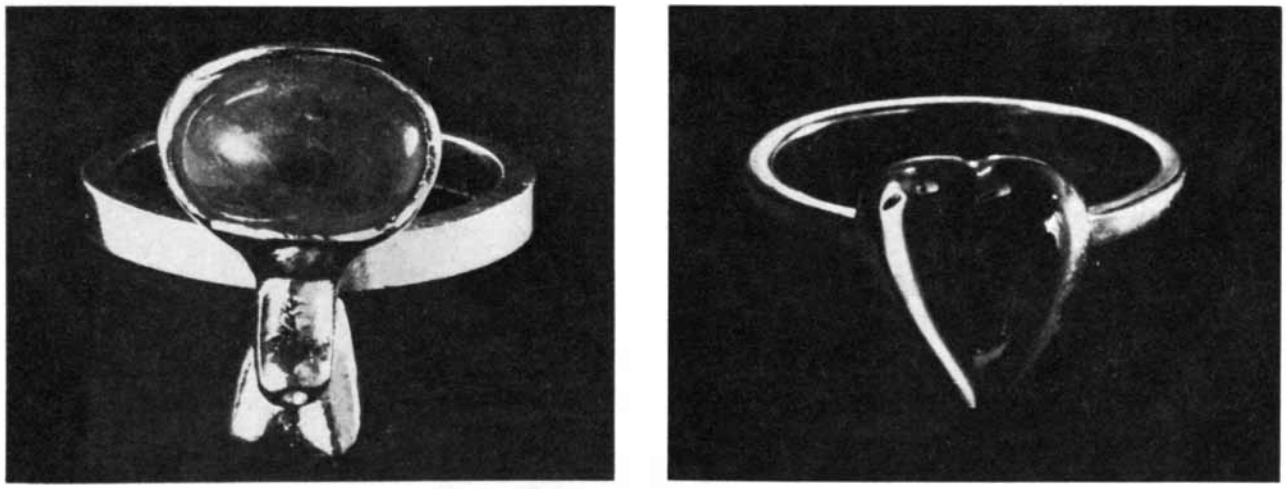


Mini David (left) ***and*** **Mini Cariatide (right)**



Rings from **Mini David (left)** ***and*** **Mini Cariatide (right)**

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be separated and reassembled in a certain order. To disassemble *Portrait de Michèle* one must first remove an element in the neck. Chinese burr puzzles tend to fall apart as soon as a few pieces are removed, but a Berrocal holds firmly together until the last two pieces are separated. In many cases the assembled model is completely solid—that is, there are no interior holes—and until piece n is removed it is impossible to remove piece $n + 1$. The interlockings are so ingenious that sometimes a piece cannot be taken out until the positions of other pieces have been slightly altered. Every multiple comes with a hardcover instruction book illustrated by Berrocal. Each stage of assembly is depicted on a separate page with the piece to be moved shown in color. At the end an isometric drawing displays the outline of all the pieces (in transparent form) after they are in place. Even when the instruction book is consulted, however, it may take several days to master the technique of taking apart and reassembling a Berrocal.

The number of pieces in a Berrocal varies from three to almost 100. Exquisite finger rings and bracelets, all wearable, are elements in many of the sculptures. For example, the pupil of Michèle's eye is the aquamarine stone of a ring. *Mini David,* the torso shown at the left in the top illustration on the opposite page, is another popular Berrocal. One of its 22 pieces is the ring shown at the left in the bottom illustration on the opposite page. The genitals of the torso hang below the gem of the ring. The entire edition of this work has been sold. It consists of six solid gold, 500 gold-plated bronze and 9,500 nickel-plated bronze multiples. In the gold-plated set the gem of the ring is green jade; in the nickel-plated set it is sapphire. Berrocal often produces "micro" versions of his works designed as pendants. There is a *Micro David* that includes a ring with a mesh band and a blue heart of lapis lazuli. The internal structure of a micro work is always completely different from that of its mini counterpart.

Mini Maria, shown in the upper illustration on the next page, can be disassembled only when a ball bearing on one leg is pressed. This sculpture is made of 23 pieces. One of them is a ring with a moonstone that forms one of Maria's breasts. Inside the figure there is a male sex organ, appearing at the left in the lower illustration on the next page, that comes apart in five pieces, two of which are steel balls. The corresponding element in the pendant *Micro Maria* has a tiny aquamarine on the tip of the organ. The gem is attached to a ring with a mesh band.

Another reclining figure, *Mini Zoriade,* opens when one shoe is rotated. Zoriade's breasts are the moonstones of

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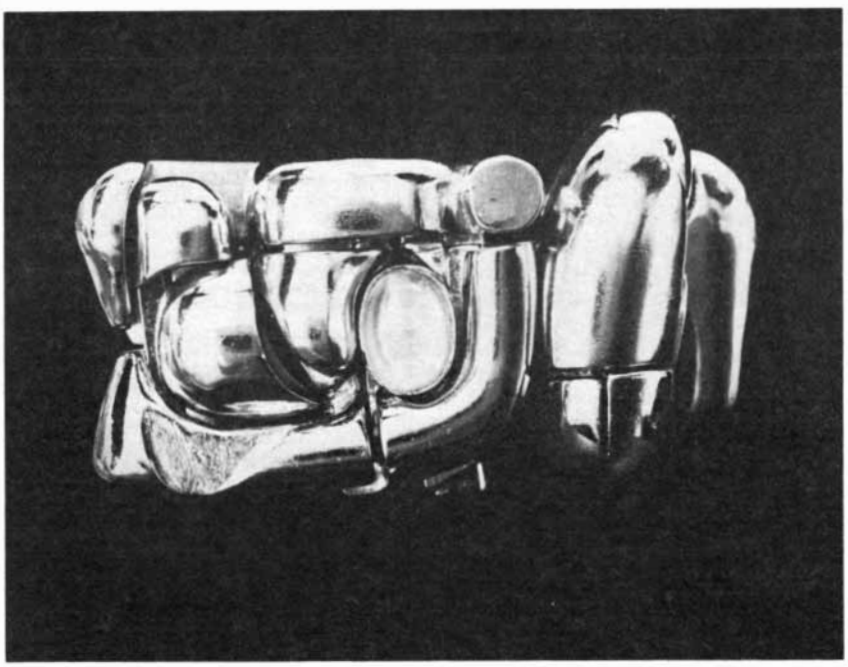
a ring. *Mini Cariatide* appears at the right in the top illustration on page 20. The mons veneris of the figure is on the gold ring appearing at the right in the bottom illustration on page 20.

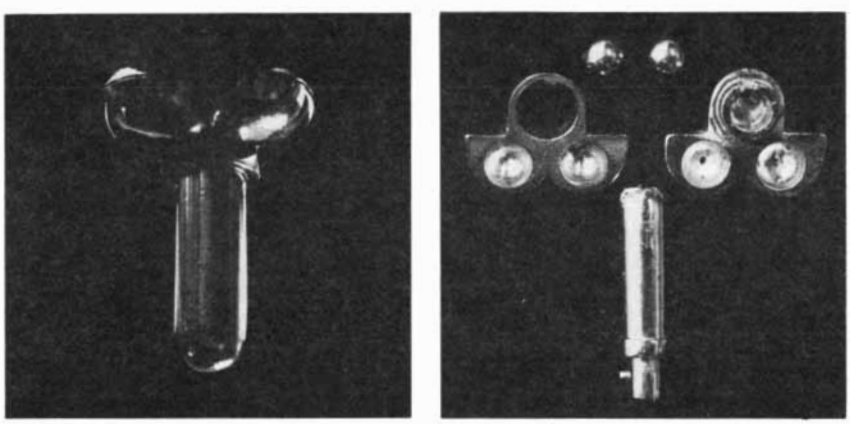
Goliath, shown in the illustration on page 14, is Berrocal's most complicated work. All 80 of its elements appear in the illustration on page 15. The sculpture is shown partially disassembled in the top illustration on page 24 to display how a Berrocal is a striking work of abstract sculpture at any stage of its assembly. When the torso of *Goliath* is completely assembled, its fig leaf can be rotated to expose the genitalia. Actually there are two pieces representing genitalia, one circumcised and one not, and the torso can be assembled with either one exposed.

Berrocal's coffin for Romeo and Juliet appears in the bottom illustration on page 24 together with an earlier 16-piece work that depicts the ill-fated lovers intertwined. Inside the lovers is a surprise best not described in a family magazine. The coffin is even more surprising. It disassembles into 84 pieces that can be refitted to make complete place settings for two: 23 pieces of silverware, four wine goblets, four candlesticks, four ashtrays, a man's dinner ring, a woman's dinner ring and a chafing dish that is larger than the coffin.

Columbia Jet, shown in the upper illustration on page 25, was commissioned by Iberia Airlines as a gift for its executives. The bird is Picasso's dove of peace. Its body is a water pitcher that pours from the dove's beak when a handle is raised. The ornate pedestal is a drinking glass. Unfold the dove's wings and landing gears descend from the wing tips. Another useful Berrocal is



Berrocal's **Mini Maria**



***An interior element of* Mini Maria (left) *and its five pieces* (right)**

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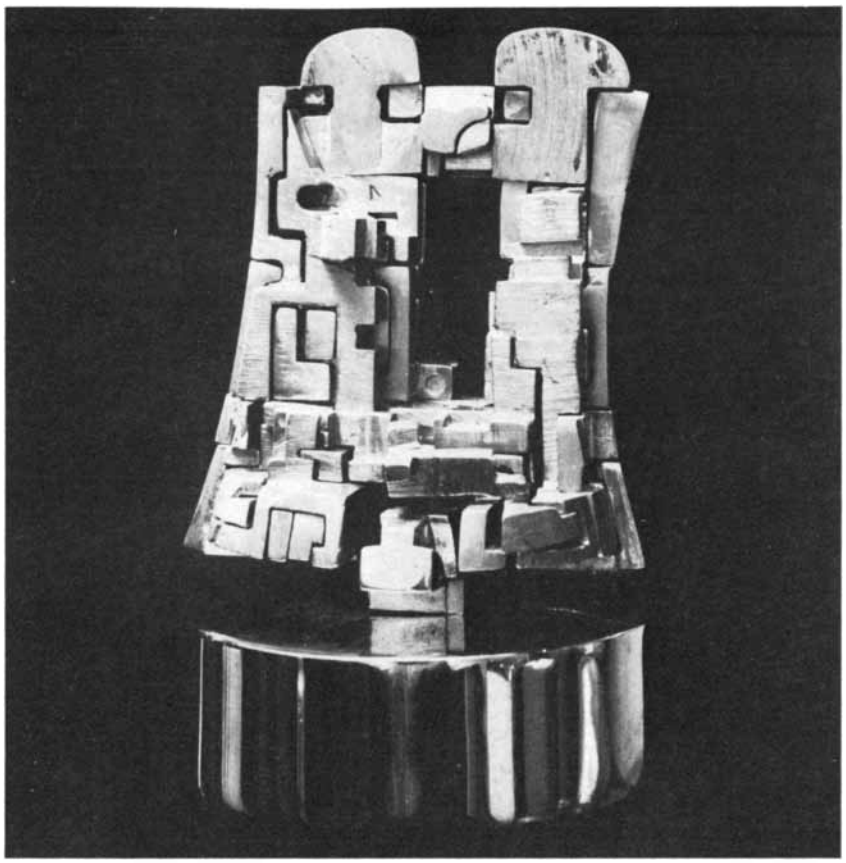
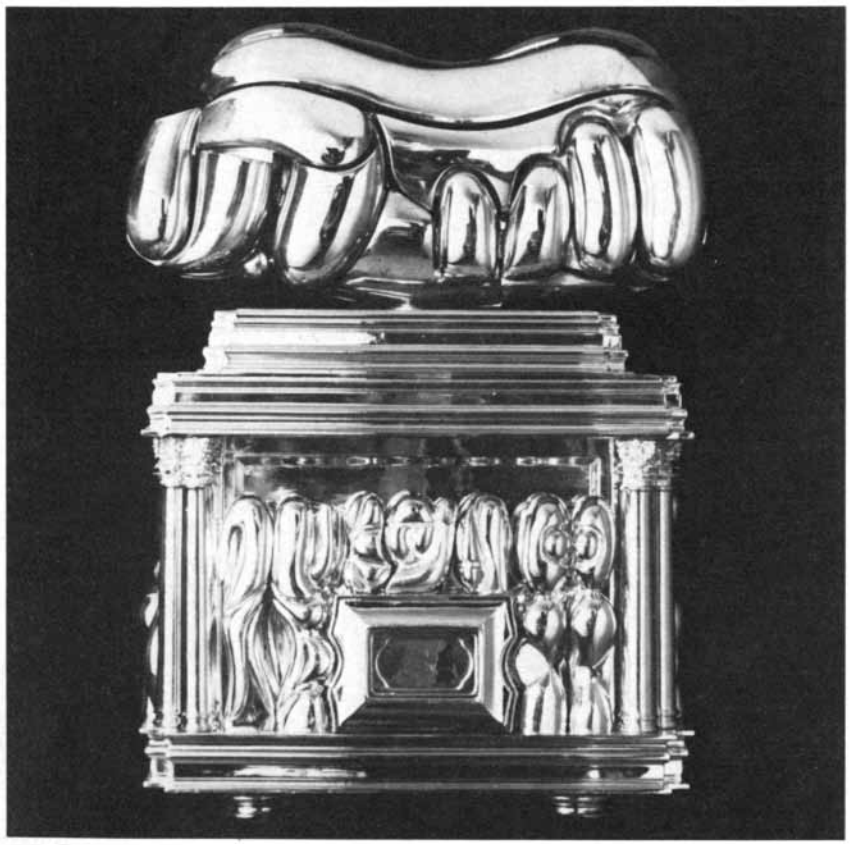


Goliath *partially disassembled*



A sculpture of Romeo and Juliet on top of another sculpture depicting their coffin

Paloma Box, a sculpture that is about a foot high and wide and opens into a jewel case with 16 felt-lined drawers. A circular mirror can be raised and then opened to reveal a sculpture of the head of Picasso's daughter Paloma. The pieces making up the head include two bracelets and two belts. Berrocal's *Il Cavallo,* shown in the lower illustration on the opposite page, has a different kind of flexibility. The 14-piece horse has legs articulated so that it can assume different positions.

I have described only a small portion of Berrocal's work. His largest sculpture is his *Homage to Picasso,* which is 18 feet long and weighs 18 tons. It is now on permanent display in the Picasso Gardens in Málaga. A miniature bronze version, *Siextasis,* consists of 20 pieces locked together by 20 small magnets. Another large sculpture, Berrocal's tribute to his good friend Dali, is in Madrid. A miniature bronze version, called *Dalirium Tremens,* will soon be available.

Berrocal's exclusive agent in the U.S. is his longtime friend and admirer James Smith Rudolph. Rudolph owns the two Centicore bookshops in Ann Arbor and Centicore Arts, International (336 Maynard Street, Ann Arbor, Mich. 48108). For many years Rudolph has supplied galleries and stores with Berrocals and arranged for about a dozen one-man shows in various cities each year. There is a show in Miami this month, and one coming up in Cleveland in February. The prices of Berrocal's works begin at $180 for the micro (pendant) multiples and rise rapidly into many thousands of dollars for the mini multiples.

There are no screws or bolts in any Berrocals except the pendants. The pendants hang by a key piece that screws in to prevent the pendant from accidentally dropping off its chain. All gold and sterling-silver mini multiples have key pieces that lock into place with an ordinary key so that the sculpture cannot be disassembled without the owner's cooperation.

Let me anticipate an objection. What, you may ask, does the fun of taking sculpture apart and putting it together again like a Chinese puzzle have to do with art? In a sense the answer is "Nothing," but that is not the whole story. The visual beauty of art has always been combined in countless ways with other values: the sexual emotions aroused by nudes; the sentiments evoked by landscapes, seascapes and family portraits; the rhetorical function of political and religious art; the didactic value of textbook illustration; the humor of comic art; the physical comfort of chairs, beds and sofas that are designed to be beautiful; the utility of tables, vases, bottles, cups, dishes, silverware, cars, houses, quilts, ships, watches, tools and so on. Berrocal's unique achievement is the combining of visual and tactile plea-

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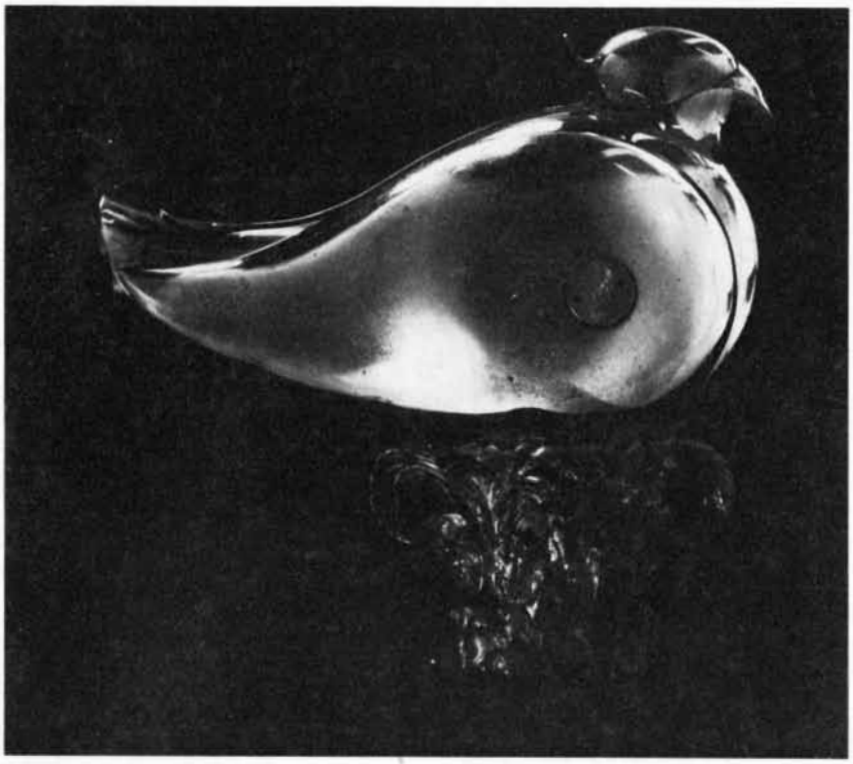
sures with the intellectual play of a mechanical puzzle. If you do not enjoy that particular combination, then a Berrocal is not for you.

In the Quadling region of Oz (as described in *The Emerald City of Oz*) the city of Fuddlecumjig is inhabited by a whimsical race of people called the Fuddles. Each Fuddle is made of hundreds of fantastically shaped pieces of painted wood that fit together like a three-dimensional jigsaw puzzle. Whenever a visitor approaches, a Fuddle clatters into a heap of disconnected parts so that the visitor will have the fun of fitting him or her together again.

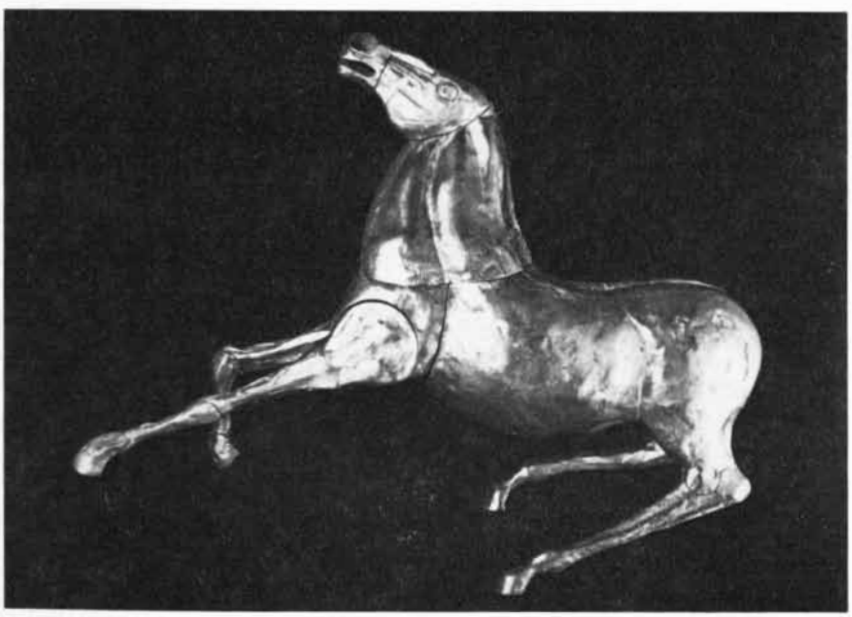
"Those are certainly strange people," Dorothy's Aunt Em said when she met the Fuddles, "but I really can't see what use they are, at all."

"Why, they amused us all for several hours," responded the Wizard. "That is being of use to us, I'm sure."

"I think they're more fun than playing



Berrocal's **Columbia Jet**



Berrocal's **Il Cavallo**

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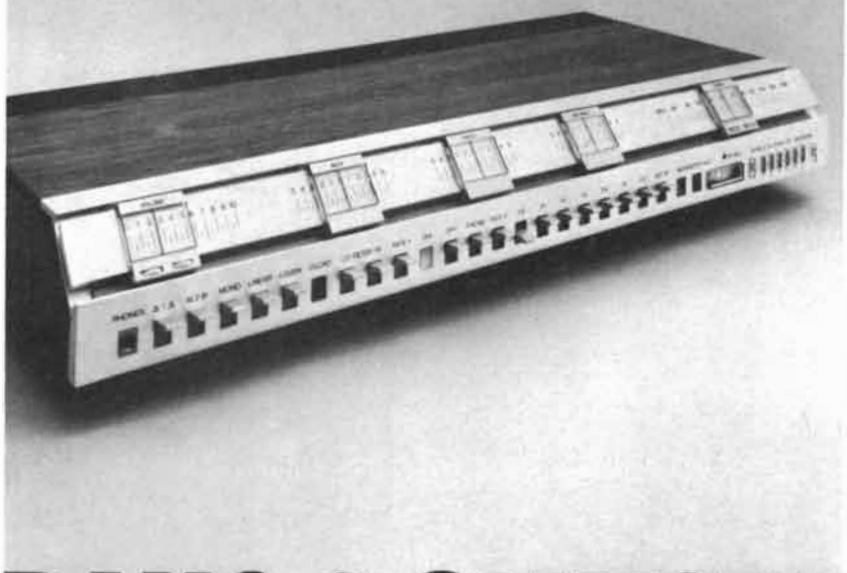

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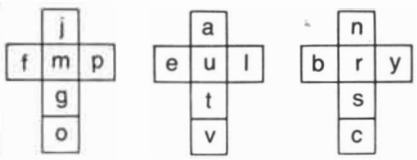

Solution to last month's calendar-cubes problem

solitaire or mumbletypeg," added Uncle Henry. "For my part, I'm glad we visited the Fuddles."

Here are the answers to Dr. Matrix' number puzzles in this department last month.

1. The problem is to prove that no number starting with 9 and followed by digits in cyclic descending consecutive order (with or without 0) can be prime. All primes except 2 must end in 1, 3, 7 or 9 because if the last digit is even, the number is divisible by 2, and if the last digit is 5, the number is divisible by 5. It is easily shown, by adding digits and reducing to the digital root, that if the sequence terminates with 1, 3, 5 or 7, the digital root must be a multiple of 3, proving that the number also is a multiple of 3.

2. In an alphabetical list of the English spellings for the integers 0 through 1,000 the next to last entry is two hundred two.

3. In an alphabetical list of the Roman numerals from 1 through 1,000 the last entry is XXXVIII, or 38.

4. The smallest number whose name contains all five vowels plus *y* is one thousand twenty-five.

5. The next term in the sequence 10^3, 10^9, 10^{27}, 10^2, 10^0 . . . is $10^{.60206\ldots}$, or 4. The first term, "one thousand," is the smallest positive integer whose English name contains *a;* the second term, "one billion," is the smallest to contain *b;* the third, "one octillion," is the smallest to contain *c;* the fourth, "one hundred," is the smallest to contain *d;* the fifth, "one," is the smallest to contain *e,* and the sixth, "four," is the smallest to contain *f.*

6. The "unfolded" cubes shown above demonstrate how three cubes can be given lowercase letters so that the cubes can be arranged in a row to spell the first three letters of any month. Note that this is possible because *u* and *n* and *p* and *d* are inverses of each other. In fact, it is possible to leave two faces unlettered, since *b* is a recognizable *g* when it is turned upside down, and *u* can double for *c* when given a quarter turn.

Many readers quite properly chided me for mentioning in my September column on hyperbolas that tossed objects follow paths that are parabolas. The paths are very close to parabolas, but strictly speaking (and ignoring air resistance) a tossed object follows an elliptical orbit around the earth's center of gravity.

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